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NEW Product

SIL10E Single

Application Note 134

1. Introduction 2

2. Models
   - Features 2

3. General Description
   - Electrical Description 2
   - Physical Construction 2

4. Features and Functions
   - Wide Operating Temperature Range 3
   - Over-Temperature Protection (OTP) 3
   - Output Voltage Adjustment 3
   - Safe Operating Area 3
   - Short Circuit Protection 3
   - Remote ON/OFF 3

5. Safety
   - Input Fusing 4

6. EMC
   - Radiated Emissions 4

7. Use in a Manufacturing Environment
   - Resistance to Soldering Heat 4
   - Water Washing 4
   - ESD Control 4

8. Applications
   - Optimum PCB Layout 5
   - Optimum Thermal Performance 5
   - Remote Sense Compensation 6
   - Output Voltage Adjustment 6
   - Output Capacitance 8
   - Output Ripple and Noise Measurement 8
   - Input Capacitance 8
   - Test Set-up 8

ARTESYN® TECHNOLOGIES

134 Rev. 02 / 26 February 2003

File Name: an_sil10e.pdf

1. Introduction

This application note describes the features and functions of Artesyn Technologies' SIL10E series of high power density, single DC/DC converters. These Point of Load modules are targeted specifically at the fixed and mobile telecommunications, industrial electronics and distributed power markets.

The SIL10E series offers a wide output voltage range of 3.3V to 0.8V VDC and can operate over an ambient temperature range of -40°C to +100°C. Ultra-high efficiency operation is achieved through the use of synchronous rectification and control techniques. The modules are fully protected against short circuit and over-temperature conditions. Standard features include remote on/off and remote sense.

The series has been designed primarily for telecommunication applications. Automated manufacturing methods, together with an extensive qualification program, ensure that all SIL10E series converters are extremely reliable.

2. Models

The SIL10E series comprises of 18 models, as listed in Table 1 .

Model	Input Voltage	Output Voltage	Output Current
SIL10E-05S0V8-V	3.0 -5.5VDC	0.8V	10A
SIL10E-05S1V0-V	3.0 -5.5VDC	1.0V	10A
SIL10E-05S1V2-V	3.0 -5.5VDC	1.2V	10A
SIL10E-05S1V5-V	3.0 -5.5VDC	1.5V	10A
SIL10E-05S1V8-V	3.0 -5.5VDC	1.8V	10A
SIL10E-05S2V0-V	3.0 -5.5VDC	2.0V	10A
SIL10E-05S2V5-V	3.0 -5.5VDC	2.5V	10A
SIL10E-05S3V3-V	4.5 - 5.5VDC	3.3V	10A
SIL10E-05W3V3-V	4.5 - 5.5VDC	3.3V	10A

To order a unit with horizontal mounting, please add the suffix '-H' to the model number e.g. SIL10E-05S3V3-H

Table 1 - SIL10E Models

Features

- High efficiency topology, typically 95% at 3.3V
- Industry standard footprint
- Wide ambient temperature range, -40ºC to +100ºC
- -75% to +10% output trim on W3V3 model
- ±10% output voltage adjustability on all other output setpoint models
- No minimum load requirement
- Remote ON/OFF
- Remote sense compensation
- Fixed switching frequency
- Continuous short-circuit protection
- Over-temperature protection (OTP)

3. General Description

3.1 Electrical Description

A block diagram of the SIL10E converter is shown in Figure 1. Extremely high efficiency power conversion is achieved through the use of synchronous rectification techniques.

The SIL topology is a non-isolated three terminal synchronous buck converter. The control of the synchronous rectifiers are optimized for high efficiency power conversion.

The output is adjustable over a range of -75% to +10% of the nominal output voltage, using the TRIM pin. This is available on the SIL10E-05W3V3 model. All other output setpoints are indicated by '**S**' e.g. SIL10E-05**S**3V3 and have a ±10% trim range.

The converter can be shut down via a remote ON/OFF input that is referenced to ground. This input is compatible with popular logic devices; a 'negative' logic input is supplied as standard. Negative logic implies that the converter is enabled if the remote ON/OFF input is low (or floating), and disabled if it is high.

The converter is also protected against over-temperature conditions. If the converter is overloaded or the ambient temperature gets too high, the converter will shut down until the temperature falls below a minimum threshold. There is a thermal hysteresis of typically 120ºC to 115ºC, to protect the unit.

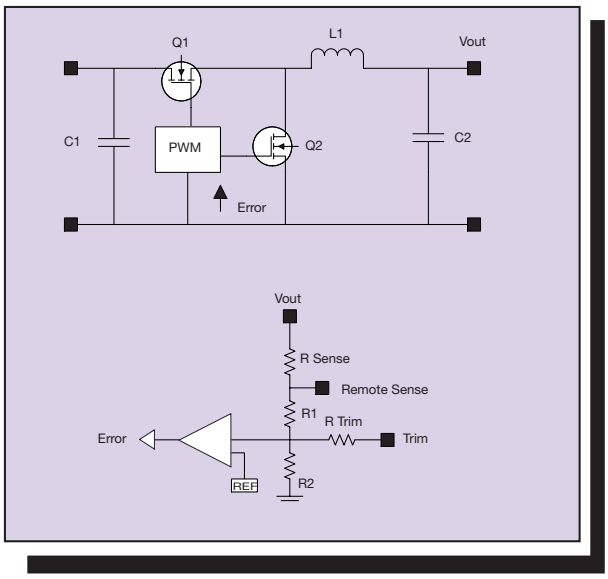


Figure 1 - Electrical Block Diagram

3.2 Physical Construction

The SIL10E is constructed using a multi-layer FR4 PCB. SMT power components are placed on one side of the PCB, and all low-power control components are placed on the other side. Heat dissipation of the power components is optimized, ensuring that control components are not thermally stressed.

The converter is an open-frame product and has no case or case pin. The open-frame design has several advantages over encapsulated closed devices. Among these advantages are:

- **Cost:** no potting compound, case or associated process costs involved.
- **Thermals:** the heat is removed from the heat generating components without heating more sensitive, less tolerant components.

- **Environmental:** some encapsulants are not kind to the environment and create problems in incinerators. Further more open-frame converters are more easily re-cycled.
- **Reliability:** open-frame modules are more reliable for a number of reasons, including improved thermal performance and reduced TCE stresses.

A separate paper discussing the benefits of open-frame DC/DC converters (Design Note 102) is available at www.artesyn.com

4. Features and Functions

4.1 Wide Operating Temperature Range

The SIL10E's ability to accommodate a wide range of ambient temperatures is the result of its extremely high power conversion efficiency and resultant low power dissipation, combined with the excellent thermal performance of the PCB substrate. The maximum output power that the module can deliver depends on a number of parameters, primarily:

- Input voltage range
- Output load current
- Air velocity (forced or natural convection)
- Mounting orientation of target application PCB, i.e. vertical/horizontal mount
- Target application PCB design, especially ground planes. These can be effective heatsinks for the converter

The SIL10E can be operated from -40ºC to a maximum ambient temperature of +100ºC. A number of design graphs are included in Figures 6, 7, 8 and 9 to simplify the design task and allow the power system designer to determine the maximum output current at which the SIL10E module may be operated for a given ambient temperature and airflow.

4.2 Over-Temperature Protection (OTP)

The SIL10E is equipped with non-latching over-temperature protection. A temperature sensor monitors the temperature of the top switch. If the temperature exceeds a threshold of 120°C (typical) the converter will shut down, disabling the output. When the case temperature has decreased by between 5ºC and 10°C the converter will automatically restart.

The SIL10E might experience over-temperature conditions during a persistent overload on the output. Overload conditions can be caused by external faults. OTP might also be entered due to a loss of control of the environmental conditions (e.g. an increase in the converter's ambient temperature due to a failing fan).

4.3 Output Voltage Adjustment

The output voltage on all models is trimmable from -10% to +10% of the nominal voltage setpoint. A wide trim model is also available that allows the user to trim from -75% to +10% of the output setpoint. This model is the SIL10E-05W3V3. Details on how to trim all models are provided in Section 8.4.

4.4 Safe Operating Area

The Safe Operating Area (SOA) of the SIL10E converter is shown in Figure 2. Assuming the converter is operated within its thermal limits it can deliver rated output current I_{rated}.

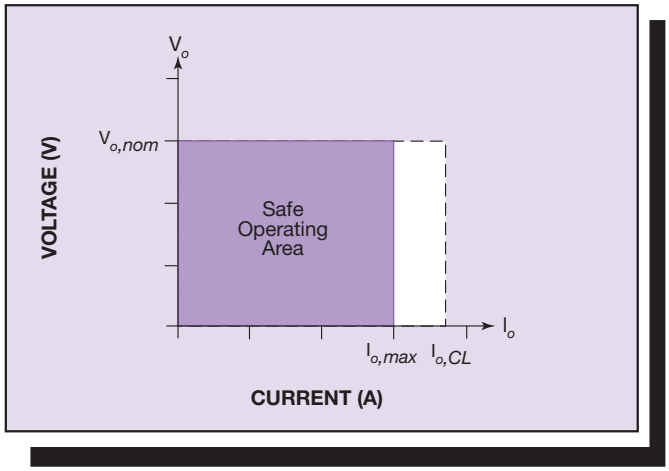


Figure 2 - Maximum Output Current Safe Operating Area

It should be noted that the SOA shown in Figure 2 is valid only if the converter is operated within its thermal specification. See Section 8.2 for more detail.

4.5 Short Circuit Protection

All SIL10E models have a full continuous short-circuit protection. The unit will auto recover once the short circuit is removed. The unit is protected only against extreme short circuits.

The unit is protected in an overload condition by the OTP function. However, we do not recommend operating the unit in a heavy overload condition as it results in the converters lifetime being reduced.

4.6 Remote ON/OFF

The remote ON/OFF input allows external circuitry to put the SIL10E converter into a low dissipation sleep mode. Active-low remote ON/OFF is available as standard.

Active-low units of the SIL10E series are turned on if the remote ON/OFF pin is low, or leaving it floating. Pulling the pin high will turn off the unit. The signal level of the remote on/off input is defined with respect to ground. The unit is guaranteed OFF if this voltage level exceeds 1.2V.

To simplify the design of the external control circuit, logic signal thresholds are specified over the full temperature range. The maximum remote ON/OFF input open circuit voltage, as well as the acceptable leakage currents, are specified in the SIL10E Long Form Datasheet. The remote ON/OFF input can be driven as described in Figure 3.

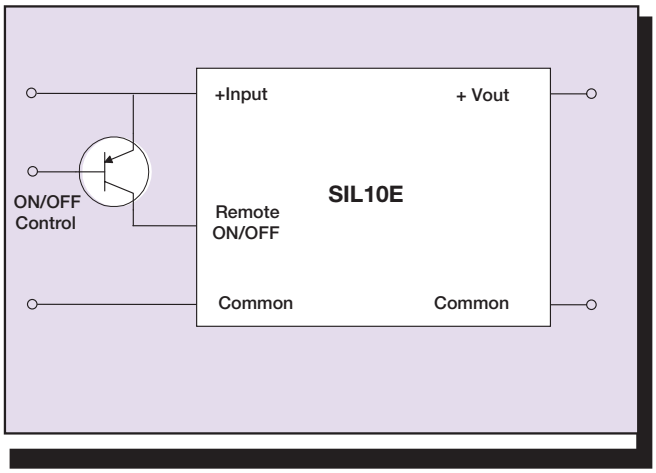


Figure 3 - Remote ON/OFF Input Drive Circuit for Non-Isolated Bipolar

5. Safety

5.1 Input Fusing

In order to comply with safety requirements, the user must provide a fuse in the unearthed input line. The reason for putting the fuse in the unearthed line is to avoid earth being disconnected in the event of a failure.

A 12.5 Amp slow-blow/anti-surge HRC (High Rupture Capacity) fuse should be used for all models.

Recommended Fuse: A - S(T) 1.25 x 0.25 inches
SIBA P/N 70 - 065/65/12.5ARS

6. Use in a Manufacturing Environment

6.1 Resistance to Solder Heat

The SIL10E series converters are intended for PCB mounting. Artesyn Technologies has determined how well the product can resist the temperatures associated with soldering of PTH components without affecting its performance or reliability. The method used to verify this is MIL-STD-202 method 210D. Within this method two test conditions were specified, Soldering Iron condition A and Wave Solder Condition C.

For the soldering iron test, the UUT was placed on a PCB with the recommended PCB layout pattern shown section 8. A soldering iron set to 350ºC±10ºC was applied to each terminal for 5 seconds. The UUT was then removed from the test PCB and examined under a microscope for any reflow of the pin solder or physical change to the terminations. None was found.

For the wave solder test, the UUT was again mounted on a test PCB. The unit was wave soldered using the conditions shown in Table 2 . The UUT was inspected after soldering and no physical change was found on the pin terminations.

Temperature	Time	Temperature Ramp
260°C±5°C	10sec±1	Preheat 4°C/sec to 160°C. 25mm/sec rate

Table 2 - Wave Solder Test Conditions

6.2 Water Washing

Where possible, a no-clean solder paste system should be used for solder attaching the SIL10E product onto application boards. The SIL10E is suitable for water washing applications, because it does not have entrapment areas where water and residues may become trapped long term. However, the user must ensure that the drying process is sufficient to remove all water from the converter after washing - never power the converter unless it is fully dried. The user's process must clean the soldered assembly in accordance with ANSI/J-STD-001.

6.3 ESD Control

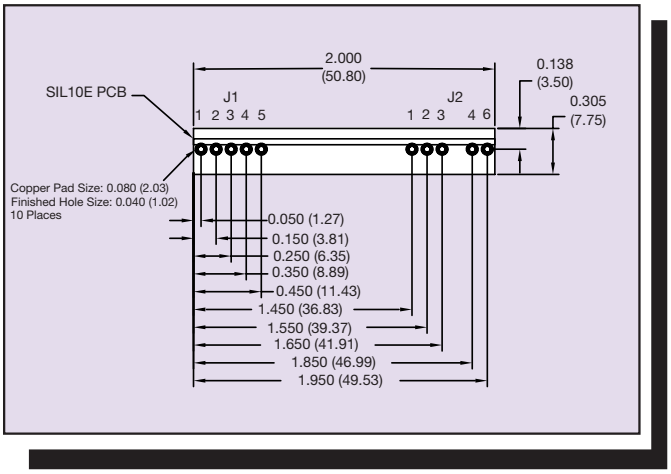
SIL10E units are manufactured in an ESD controlled environment and supplied in conductive packaging to prevent ESD damage occurring before or during shipping. It is essential that they are unpacked and handled using approved ESD control procedures. Failure to do so could affect the lifetime of the converter.

7. Applications

7.1 Optimum PCB Layout

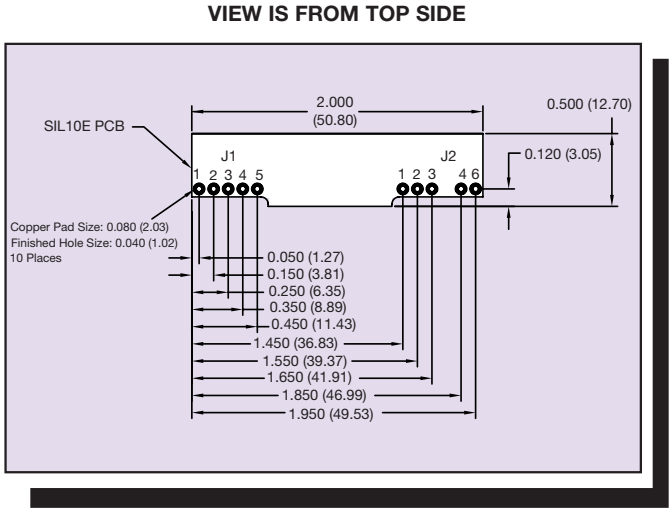
The PCB acts as a heat sink and draws heat from the unit via conduction through the pins and through radiation. The end user must ensure that other components and metal in the vicinity of the SIL10E meet the spacing requirements to which the system is approved. Low resistance and low inductance PCB layout traces should be used where possible, particularly when high currents are flowing (e.g. the output side). A low impedance track should connect input ground and output ground to maximize efficiency of the unit.

VIEW IS FROM TOP SIDE



ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 4a - Recommended Footprints (Vertical Mount)



ALL DIMENSIONS IN INCHES (mm)
ALL TOLERANCES ARE ±0.004 (0.10)

Figure 4b - Recommended Footprints (Horizontal Mount)

7.2 Optimum Thermal Performance

The electrical operating conditions of the SIL10E, namely:

- Input voltage, V_{in}
- Output voltage, V_o
- Output current, I_o

determine how much power is dissipated within the converter. The following parameters further influence the thermal stresses experienced by the converter:

- Ambient temperature
- Air velocity
- Thermal efficiency of the end system application
- Parts mounted on system PCB that may block airflow
- Real airflow characteristics at the converter location

The maximum acceptable temperature measured at the thermal reference points is 115°C. These thermal reference points are shown in Figure 5.

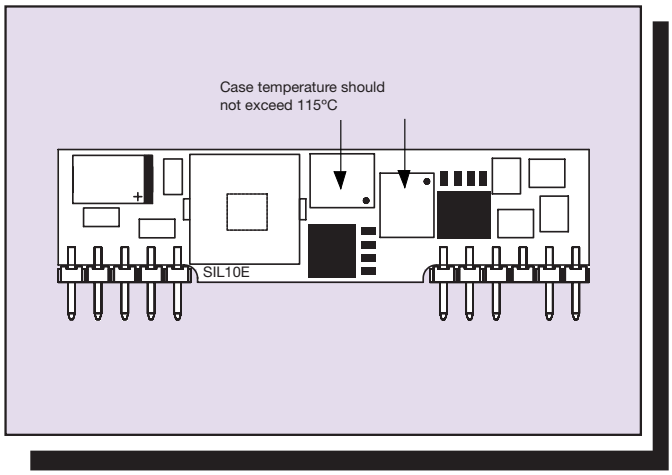


Figure 5 - Thermal Reference Point Locations on SIL10E Converters

In order to simplify the thermal design, a number of graphs are given in the data sheet and are repeated in Figures 6, 7, 8 and 9. These derating graphs show the load current of the SIL10E versus the ambient air temperature and forced air velocity. However, since the thermal performance is heavily dependent upon the final system application, the user needs to ensure the thermal reference point temperatures are kept within the recommended temperature rating. It is recommended that the thermal reference point temperatures are measured using a thermocouple or an IR camera. In order to comply with stringent Artesyn derating criteria the ambient temperature should never exceed 100°C. Please contact Artesyn Technologies for further support.

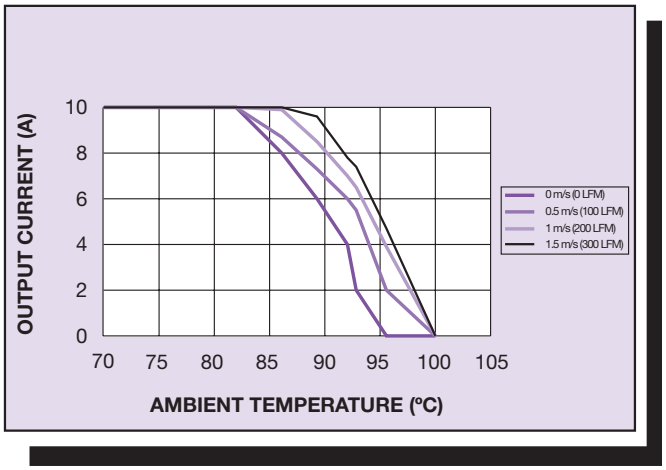


Figure 6 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL10E-05W3V3, with V_{in} = 5V and No Trim

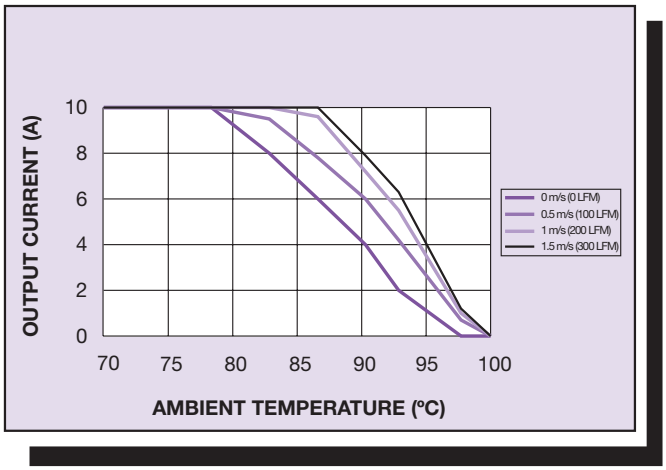


Figure 7 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL10E-05W3V3, with V_{in} = 5V and Full Trim down, V_{out} = 0.8V

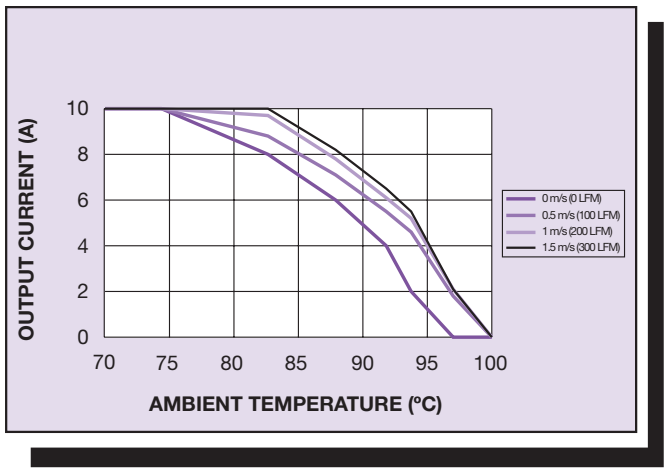


Figure 8 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL10E-05S2V5, with V_{in} = 3.3V and No Trim

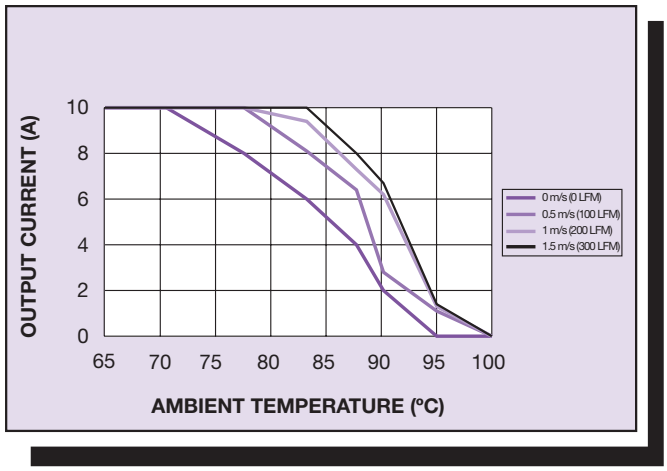


Figure 9 - Maximum Output Current vs. Ambient Temperature and Airflow for SIL10E-05S2V5, with V_{in} = 5V and No Trim

7.3 Remote Sense Compensation

The remote sense compensation feature minimizes the effect of resistance in the distribution system and facilitates accurate voltage regulation at the load terminals or another selected point. The remote sense line will carry very little current and hence do not require a large cross-sectional area. However, if the sense line is routed on a PCB, it should be located close to a ground plane in order to minimize any noise coupled onto the lines that might impair control loop stability. A small 100nF ceramic capacitor can be connected at the point of load to decouple any noise on the sense wires. The module will compensate for a maximum drop of 10% of the nominal output voltage. However, if the unit if already trimmed up, the available remote sense compensation range will be correspondingly reduced. Remember that when using remote sense compensation all the resistance, parasitic inductance and capacitance of the distribution system are incorporated into the feedback loop of the power module. This can have an effect on the module's compensation capabilities, affecting its stability and dynamic response.

7.4 Output Voltage Adjustment

The output can be externally trimmed by ±10% by connecting an external resistor between the TRIM pin and either the V_{sense+} or Ground pin. With an external resistor between TRIM and ground, R_{TRIM_UP}, the output voltage setpoint increases. Conversely, connecting an external resistor between TRIM and V_{sense+}, R_{TRIM_DOWN}, the output voltage set point decreases. This is shown in Figures 10 and 11. A wide trim version allows the user to trim down to 0V8 Volts, as shown in Figure 14.

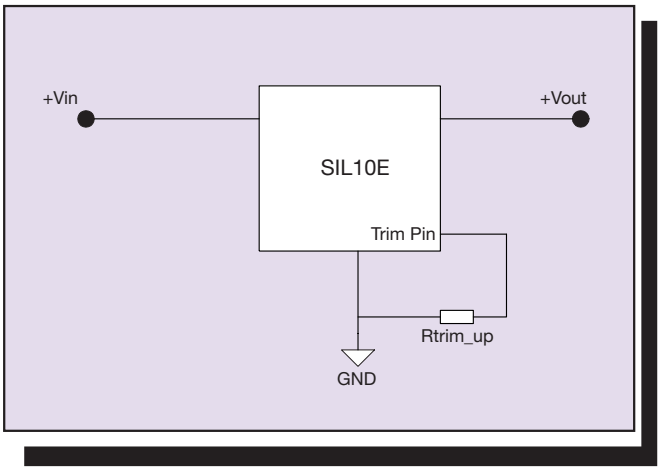


Figure 10 - Trimming Output Voltage - Trim up

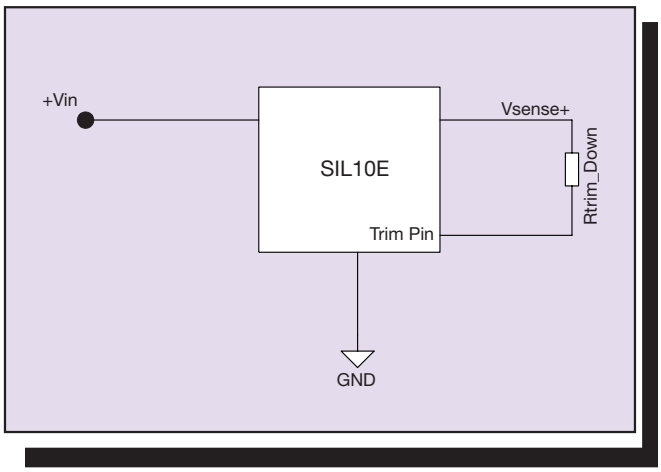


Figure 11 - Trimming Output Voltage - Trim Down

The relevant trim equations to derive the appropriate trim resistance for the SIL10E are as follows

$$R_{TU} = K \frac{Au - Vout\ Bu}{Cu\ Vout - Du}$$

Where,
R_{tu} = Trim Resistor from trim To GND
Vout = Desired O/P trim setpoint

and the following parameters are defined:

	K	Au	Bu	Cu	Du
S0V8	10^5	16.14	18.06	26.80	21.43
S1V0	10^5	44.73	39.71	66.4	68.95
S1V2	10^5	4.47	3.02	11.33	14.26
S1V5	10^5	35.85	20.07	26.80	40.39
S1V8	10^5	5.17	2.59	2.46	4.43
S2V0	10^5	3.51	1.57	1.65	2.32
S2V5	10^5	11.50	4.11	5.50	13.74
S3V3	10^5	8.27	2.25	3.92	12.93
W3V3	10^5	7.70	2.08	1.69	5.57

$$RTD = K \frac{Ad - Vout\ Bd}{Vout\ Cd - Dd}$$

R_{td} = Trim Resistor from trim To V_{sense}
Vout = Desired O/P trim down setpoint

Where	K	Ad	Bd	Cd	Dd
S0V8	10^5	16.14	22.48	26.80	21.43
S1V0	10^5	44.73	49.70	66.40	68.95
S1V2	10^5	4.47	4.20	11.83	14.26
S1V5	10^5	35.85	28.00	26.80	40.39
S1V8	10^5	5.17	3.33	2.46	4.43
S2V0	10^5	3.51	2.07	1.65	3.32
S2V5	10^5	11.50	5.76	5.50	13.70
S3V3	10^5	8.27	3.43	3.92	12.93
W3V3	10^5	7.70	9.90	1.69	5.57

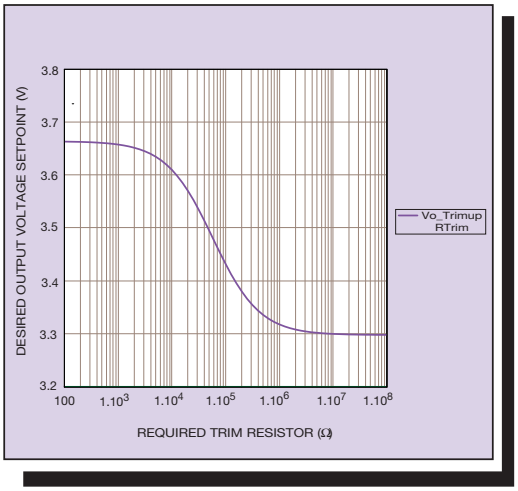


Figure 12 - Typical Trim Up Curve for SIL10E-05S3V3 (Resistor from Trim to Common)

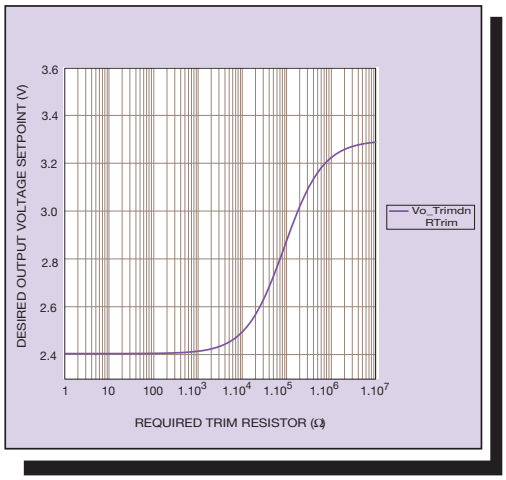


Figure 13 - Typical Trim Down Curve for SIL10E-05S3V3 (Resistor from TRIM to V_{sense+})

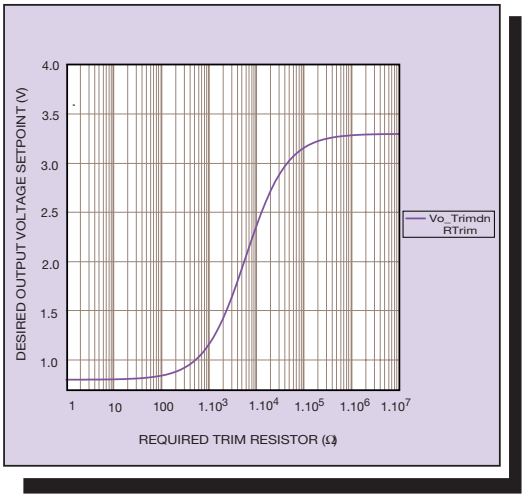


Figure 14 - Typical Trim Down Curve for SIL10E-05W3V3 (Resistor from Trim to V_{sense}+)

7.5 Output Capacitance

The SIL10E series has been designed for stable operation without the need for external capacitance at the output terminals. However, when powering loads with large dynamic current requirements, improved voltage regulation can be obtained by inserting capacitors as close as possible to the load. The most effective technique is to locate low ESR ceramic capacitors as close to the load as possible, using several capacitors to lower the overall ESR. These ceramic capacitors will handle the short duration high frequency components of the dynamic current requirement.

It is equally important to use good design practices when configuring the DC distribution system. Low resistance and low inductance PCB layout traces should be utilized, particularly in the high current output section. Remember that the capacitance of the distribution system and the associated ESR are within the feedback loop of the power module. This can have an effect on the module's compensation capabilities and its resultant stability and dynamic response performance. With large values of capacitance, the stability criteria depend on the magnitude of the ESR with respect to the capacitance. As much of the capacitance as possible should be

outside the remote sensing loop and close to the load.
Note that the maximum rated value of output capacitance for all models is 10,000µF. Contact your local Artesyn Technologies representative for further information if larger output capacitance values are required in the application.

7.6 Output Ripple and Noise Measurement

The measurement set-up outlined in Figure 15 has been used for output voltage ripple and noise measurements on SIL10E series converters. When measuring output ripple and noise, a 50Ω coaxial cable with a 50Ω termination should be used to prevent impedance mismatch reflections disturbing the noise readings at higher frequencies.

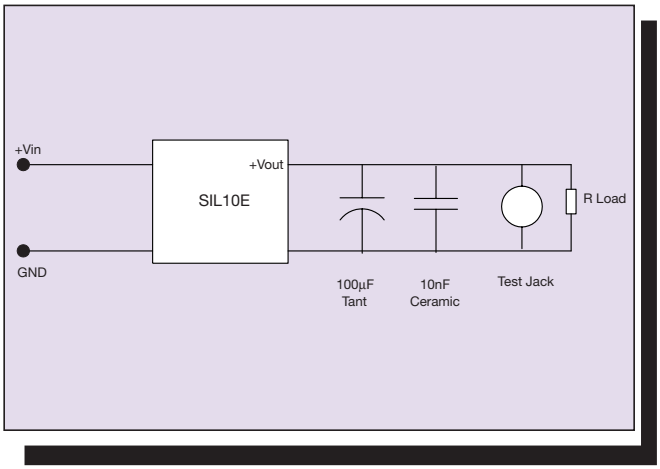


Figure 15 - Output Voltage Ripple and Noise Measurement Set-Up

7.7 Input Capacitance

The SIL10E converter must be connected to a low AC source impedance. High source inductance can affect the loop stability. Input capacitance should be placed close to the converter input pins to decouple distribution inductance. The external input capacitors must be chosen for suitable ripple current rating. Electrolytic capacitors should be avoided. Recommended input capacitors are ceramics such as 10µF 10V 1812 or similar.

7.8 Test Set-up

This converter is non-isolated, that is, the input and output share a common ground. These grounds should be connected together via a low impedance ground plane in the application circuit. When testing a converter on a bench set-up, ensure that V_{in}- and V_o- are connected together via a low impedance short to ensure proper efficiency and load regulation measurements are being made. When testing the SIL10E under any transient conditions please ensure that the transient response of the source is sufficient to power the equipment under test. Under some test conditions it may be necessary to power the unit with a half brick such as an Artesyn Technologies EXB250.